Timing Information at CMS

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Outline

- Motivation
- Timing information at CMS
- Muon timing from *W->munu* MC
- Muon timing from *CRAFT* data
- Compare *In-Time* muons from IP and Cosmic
- *Out-of-Time* Cosmic Muon in collision mode
- Summary and plans

Motivation

• Reject backgrounds from cosmic rays, which pass closely to IP and create fake MET

• There are kinematic ways to reject the cosmics, but *this talk is limited to use timing info*

• Timing information is useful since cosmics arrival randomly and do not correlate with LHC crossing time.

- *The tracker* do not carry timing information within 25 ns, thus not useful

-Both *Ecal and Hcal* measure the scintillation light pulses, enabling a timing measuremennt better than 25ns (more details in coming slides)

-All muon sub-detectors (*DT, RPC and CSC*) can measure time within several ns. Only DT timing is used to provide timing information in reco::Muon object

Hcal Timing

- Each Hcal signal is sampled with LHC BX 40MHz clock.
- It measures signal times < 25 ns due the light pulse shape spread over 3-4 samples

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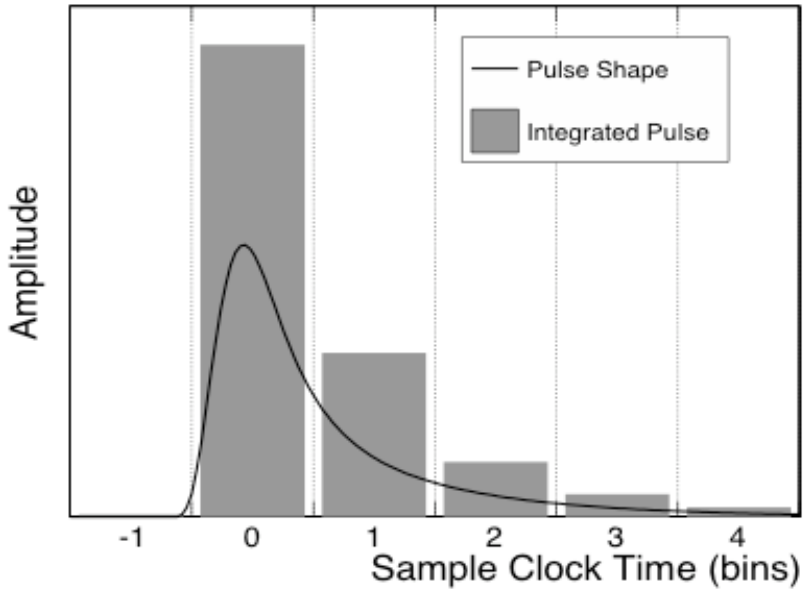
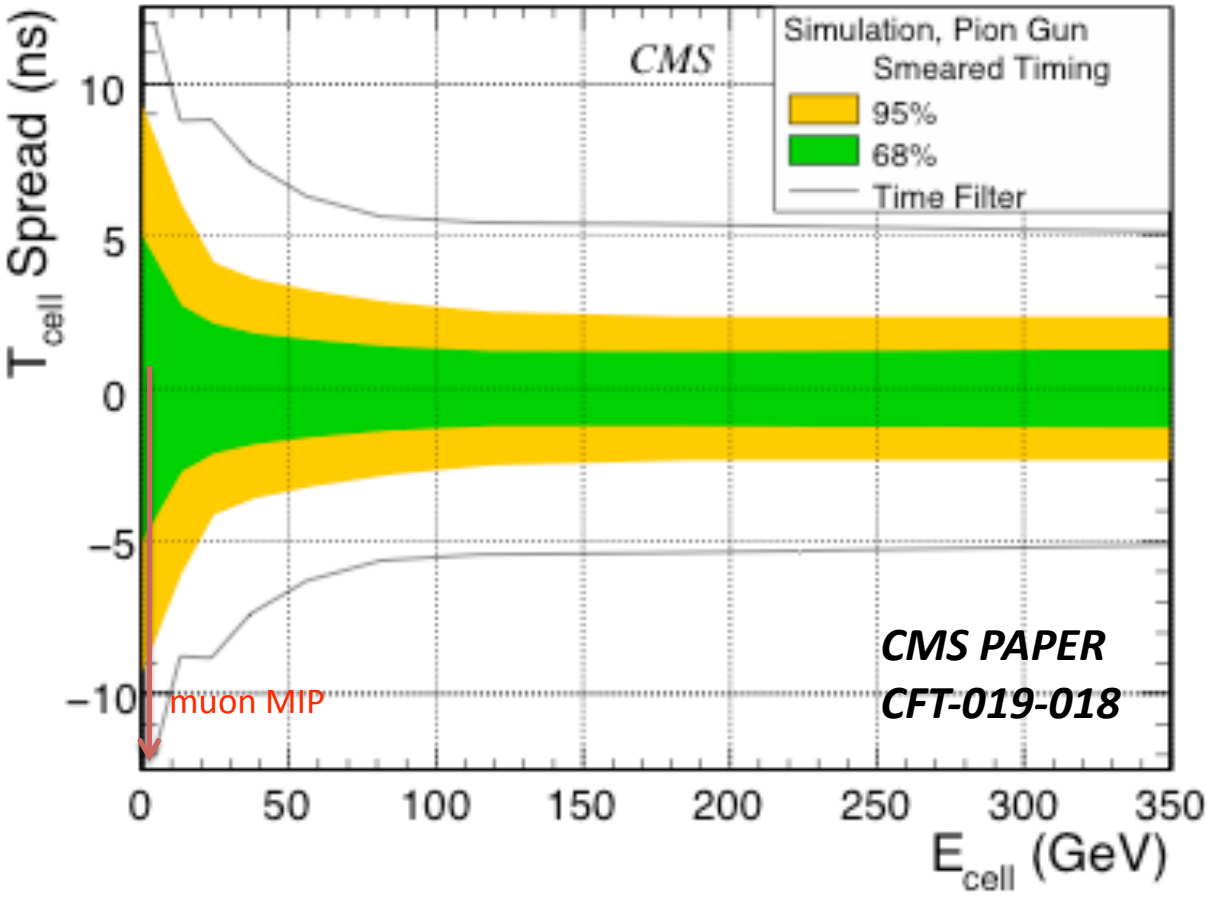


Figure 3: The HCAL pulse shape and its relation to the integrated samples. Time sample 0 is defined by the trigger.

- *Upon the receipt of L1A, light pulse of 10 time samples are analyzed*
- *This is after the time-alignment and synchronization to LHC collision, during which timing variations between different cells due to the different TOF from IP, various latency difference are calibrated and subtracted.*
- *Testbeam data indicates HCAL can be synchronized within 1ns*

Hcal Timing Resolution

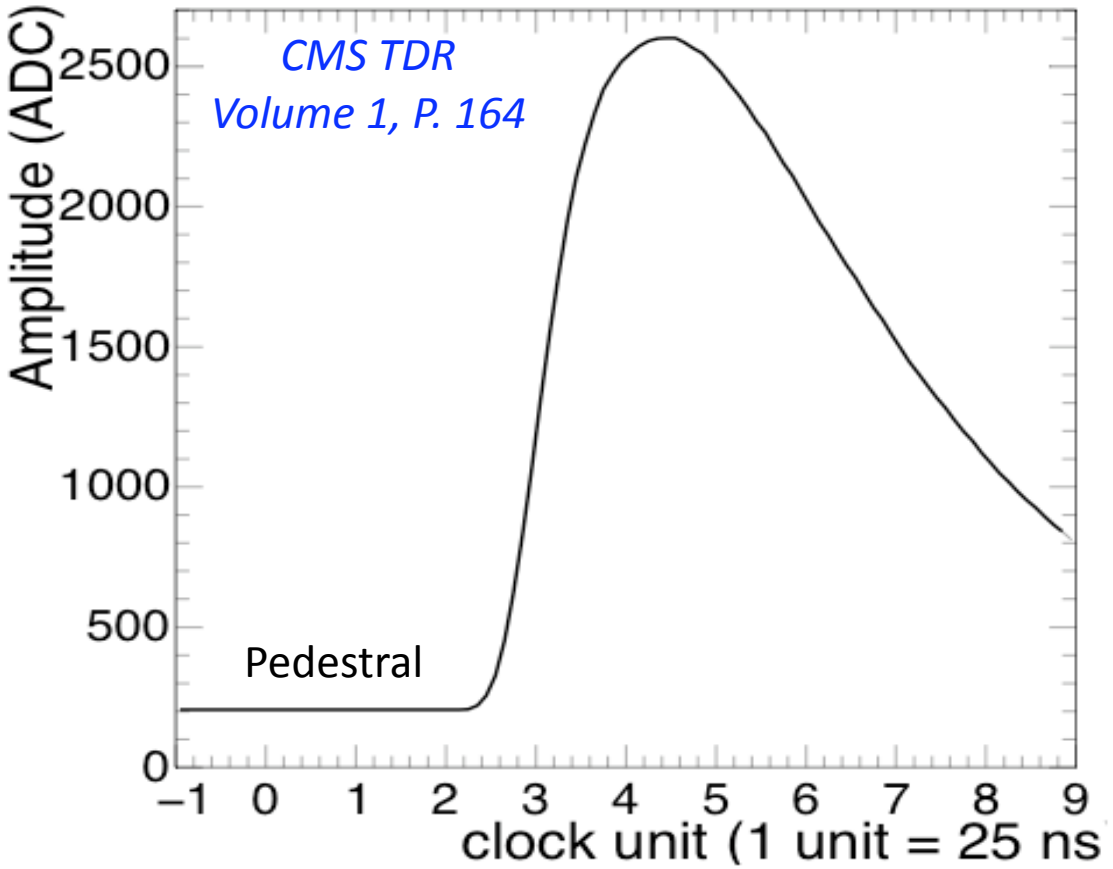
- *Timing resolution as a function of energy of reconstructed deposits from MC*



- *Muon energy deposit in Hcal is mainly MIP (~ 1.8 GeV), the resolution ~ 10ns*

Ecal Timing

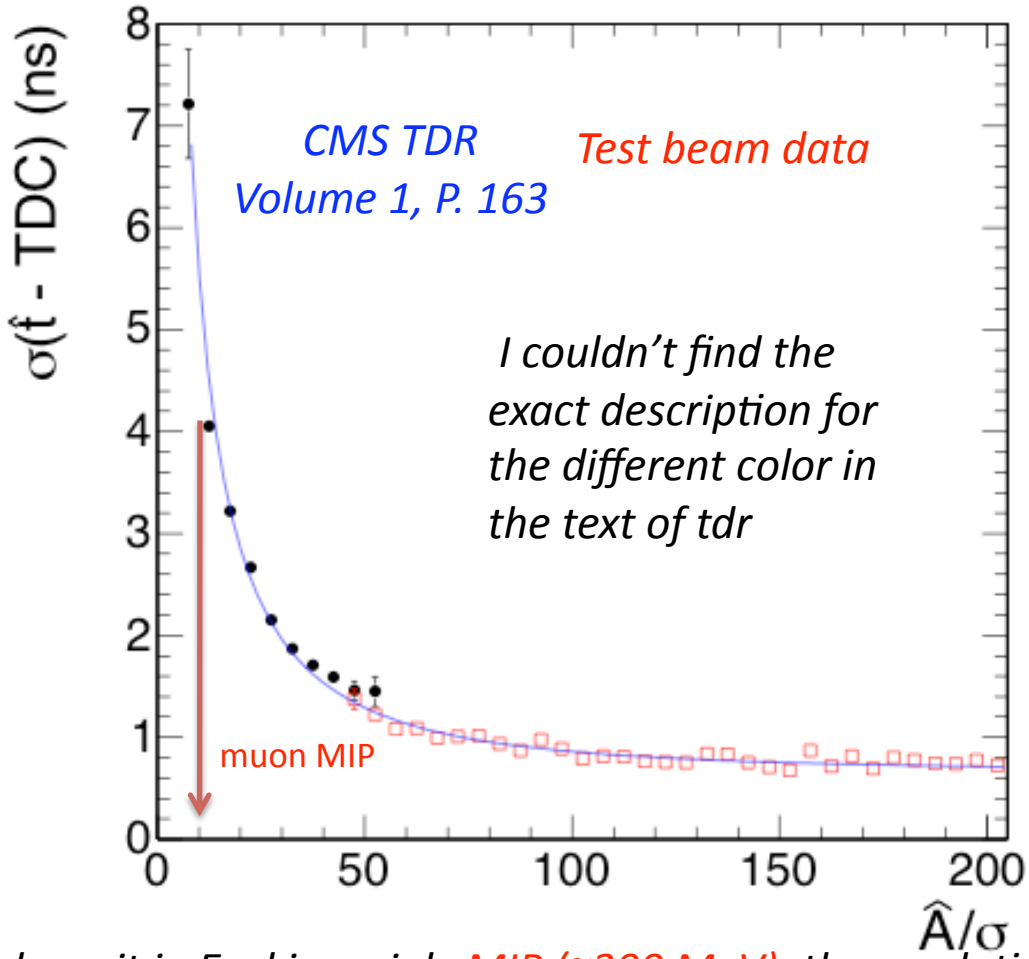
- Each Ecal signal is sampled with LHC BX 40MHz clock.
- Similar to Hcal, it measures signal pulse shape in 10 time samples
- By fitting the pulse shape, the peak time can be obtained better than 25ns



Signal pulse profile of a crystal from 120 GeV electron test-beam data

Ecal Timing Resolution

- The *Ecal timing resolution wrt signal/noise amplitude*, with *noise = 40 MeV*
- Timing resolution measured with two different methods, one is "digital filtering technique", the other is measured with test-beam trigger time given by TDC



- *Muon energy deposit in Ecal is mainly MIP (~300 MeV), the resolution ~ 10ns*

Muon System Timing

• DT, RPC and CSC all provide timing information, but only DT timing is used to provide timing information in RECO. *RPC timing are mainly used for L1 Trigger in BX ID, and and CSC timing is not well calibrated to provide reliable timing*

• Time measured by a DT cell has the following contributions

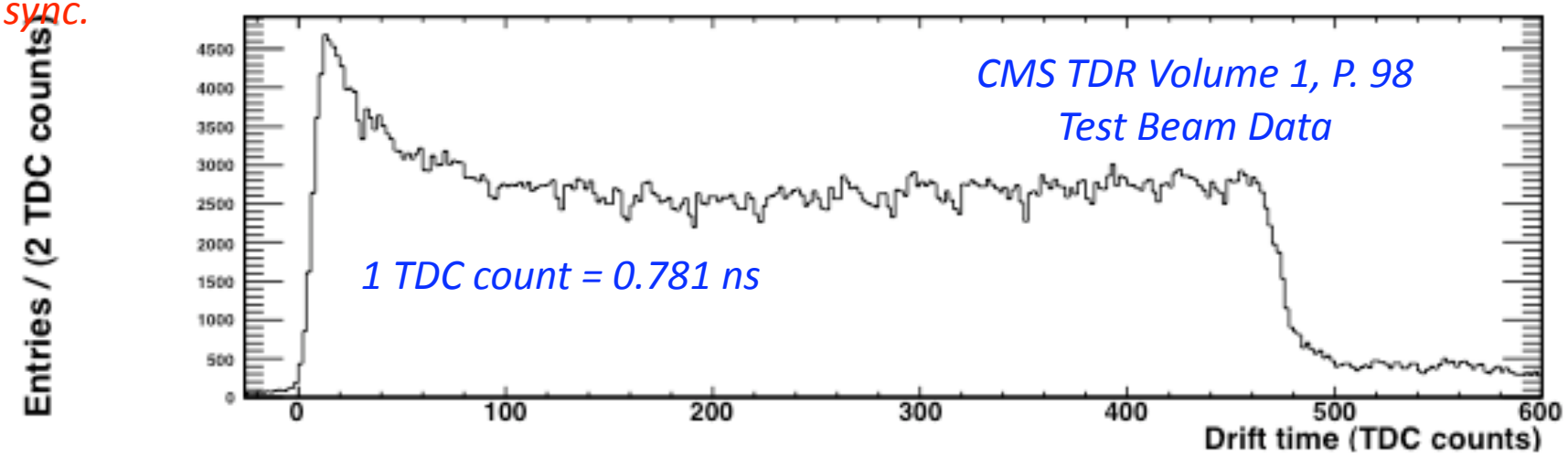
1. *Electron drift time in the gas (<=380 ns)*
2. TOF from the IP
3. Global offset to LHC or trigger time
4. Propagation time of the signal along the wire

• 2 and 3 are done by local calibration and global synchronization

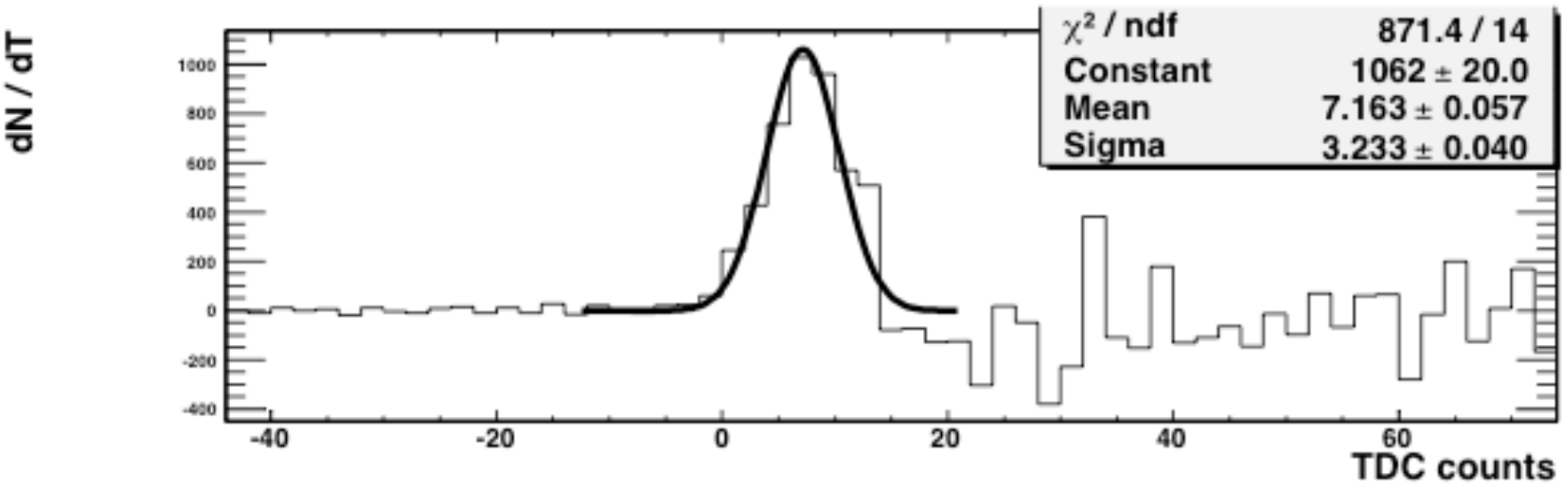
• 4 is calibrated in the inter-channel synchronization

Muon DT Drift Time

- Arrival time recorded by TDC in all cells in one chamber superlayer *after relative t0 sync.*



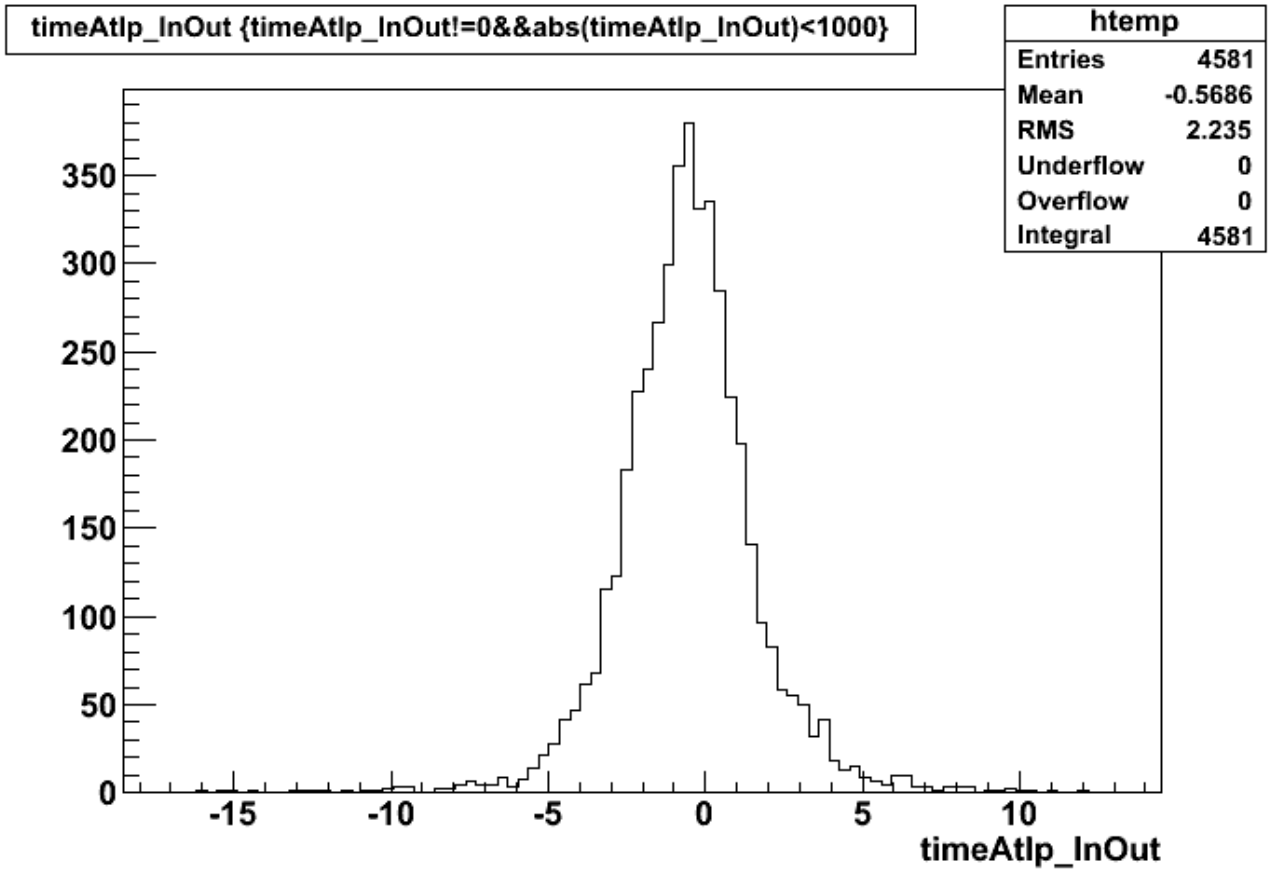
- *Fit derivative distribution* with Gaussian and obtain the peak



- Muon arrival time is: Mean – 2*sigma, with < 3 ns resolution

Muon Timing from W->mu nu MC

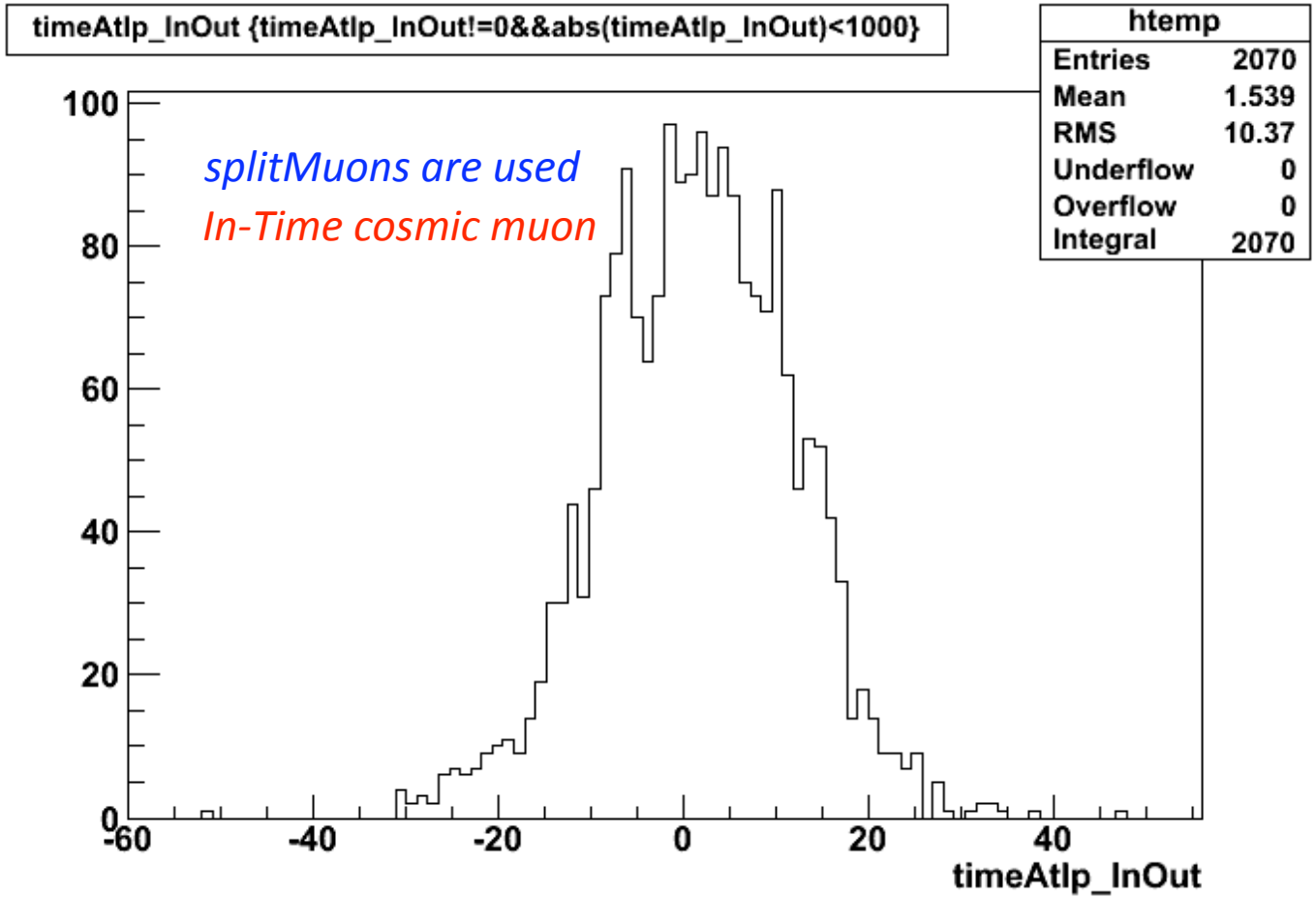
- Data Sample: /store/mc/Summer09/Wmunu/GEN-SIM-RECO/MC_31X_V3-v1
- Release: CMSSW 3_2_3; muons are just ootb "muons" collection with no cuts



- timeAtIp_InOut: a weighted average of time measurement (local_t0) in all segments
  RecoMuon/MuonIdentification/src/MuonTimingFiller.cc:
  *107: vertexTime+=tmSeq.local_t0.at(i)*tmSeq.weight.at(i)/tmSeq.totalWeight;*
- local_t0 is measured wrt trigger time and synchronized to account for TOF and latencies.

CRAFT MuonTiming

- Data Sample: /Cosmics/CRAFT09-CRAFT09_R_V4_CosmicsSeq_v1/RECO
- Release: CMSSW 3_2_3; muons are just ootb "splitMuons" collection with no cuts

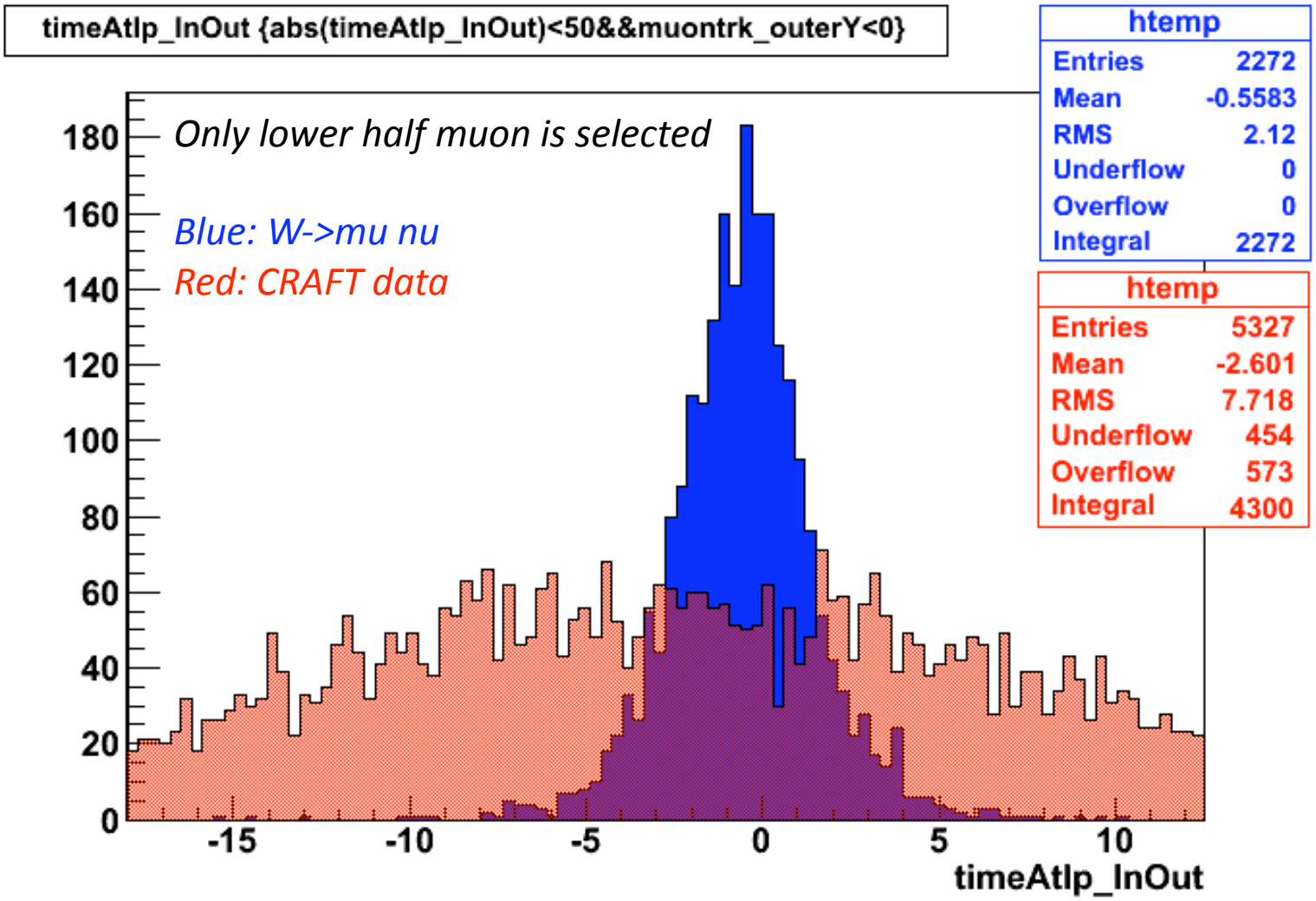


- local t0 of each drift cell is synchronized according to *the cosmic out-in direction*
- It can be directly compared with *In-time (out-going) cosmic muon* bkg in collision mode

Compare In-Time muons from IP and Cosmic

• In-time (out-going) cosmic muons are reconstructed the same way as muons from IP. without sync issues

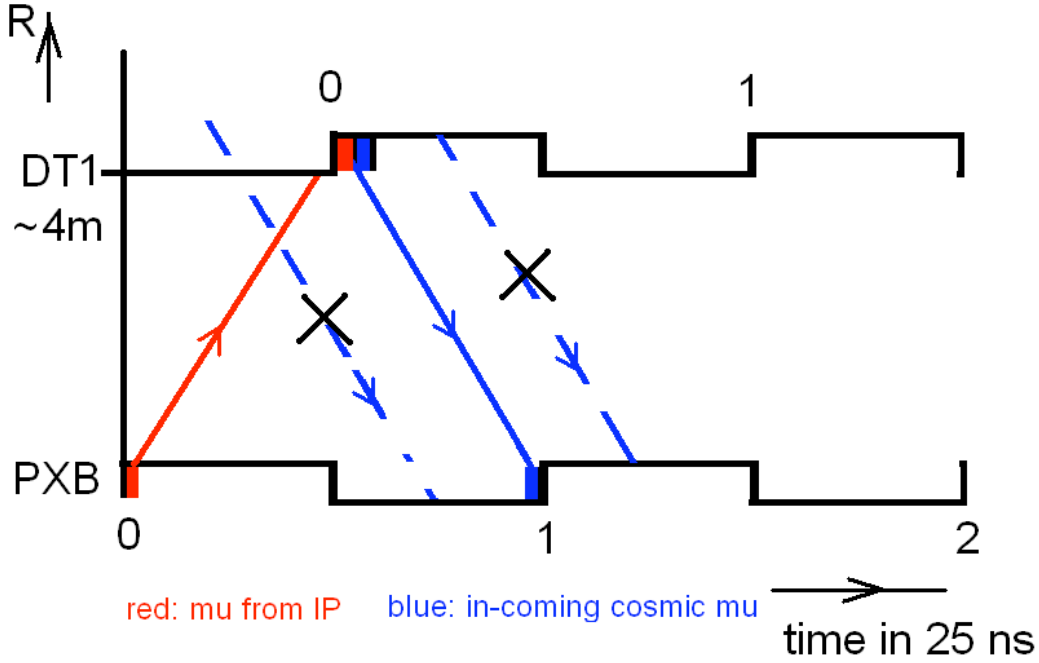
Direct overlay without considering normalizations



Out-of-Time Cosmic Muons

• To fake in di-lepton FS, the out-of-time (in-coming) cosmic muon will *most likely have*
-at least 1 pixel hit and 1 muon hit

• Since this in-coming cosmic muon is running against the aligned clock, the arrival time difference in muon DT and pixel layer is at least twice the TOF (DT-Pixel), about 1 BX.



It is rare to assign both hits to the same BX

• If it is reconstructed due to lhc sync. uncertainty or inefficiency in hits assigning BX, then the *muon_time – ecal_time* is different for collision and cosmic muon.

Muons coming from IP : 0 (+/- 3ns)
Incoming cosmic muon : a shift in the mean reflecting the 2*TOF (DT->Ecal)

Summary

•Briefly discussed CMS timing information from Ecal, Hcal and muon DT

-Ecal and Hcal resolution depend on the energy deposit

-Resolution for MIP deposit in Ecal and Hcal are about 10 ns

-Time resolution using DT for a muon is about 3ns

• Explored a bit the possible ways to reject cosmic muon using only DTmuon timing with W->mu nu MC and CRAFT09 data

-In-time (out-going) cosmic muons can be distinguished from muon from IP by the dispersion of the arrival time

-Out-time (in-coming) cosmic muons are most likely vetoed if requiring both DT and Pixel hits

Plans in the near future

1. Investigate further timing from Ecal and Hcal to see if it is possible to correlate them with DT timing to distinguish cosmic and collision muons.
2. Check into different MC samples besides W->munu
3. Reconstruct cosmic MC in collision mode to learn more cosmic muon timing shapes
4. Develop a selection cut to optimize the S/B

BACKUP Slides

Hcal Timing Filter

- Out-of-time filter is applied on CRAFT

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